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The relation between mathematics students' discipline-based epistemological beliefs and their summative assessment preferences

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Abstract Existing research posits a relationship between undergraduate mathematics students' mathematics-related epistemological beliefs and their perceptions of summative assessment. This paper reports a study investigating whether there is indeed such a relationship. First and second year mathematics undergraduate students at two universities in the UK were invited to complete a questionnaire, comprising the Assessment Preference Inventory and the Mathematics-Related Beliefs Questionnaire. The results did not support the prediction, with the only statistically significant relation found being one between students' self-efficacy and their preference for summative assessment methods requiring complex responses. We conclude either that the prediction of the relationship is mistaken, or that concerns about the definition of discipline-based epistemological beliefs, the uniformity of the sample in the study or the issue of validity of the tools used to measure epistemological beliefs may mask the nature of this relationship.

Keywords Summative Assessment · Epistemological Beliefs · Student Preferences

1 Introduction

Students' epistemological beliefs appear to have an effect on (and are affected by) many different areas of the teaching and learning process. Hofer (2001) argues that, amongst other educational processes, students' beliefs about the nature of knowledge directly affect their motivation, their beliefs about learning and education and their choice of strategies for approaching classroom tasks.

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Schommer, Crouse, and Rhodes (1992) found a relationship between epistemological beliefs and mathematics text comprehension; Tsai (2000) found a relationship between students' epistemological beliefs and perceptions of constructivist-based learning environments and Mason, Boscolo, Tornatora, and Ronconi (2013) found direct links between science students' epistemological beliefs and their knowledge acquisition, mastery and achievement goals such as performance-approach or performance-avoidance goals.

DeBacker and Crowson (2006) and Ravindran, Greene, and DeBacker (2005) noted a link between epistemological beliefs and engagement with learning and many studies have noted the link between engagement with learning and summative assessment preference (e.g. Gijbels & Dochy, 2006; Birenbaum, 2007; Furnham, Batey, & Martin, 2011). This research implies the existence of a relationship between epistemological beliefs and summative assessment preference and Iannone and Simpson (2016) directly posit the existence of such a link. Surprisingly few studies, however, have sought direct evidence for the relationship between summative assessment preference and epistemological beliefs. This paper reports on a study with undergraduate mathematics students to establish whether there is such a link and, if so, what sub-concepts play key roles in that relationship.

2 Literature Review

2.1 Students' perceptions of summative assessment

The seminal work by Marton and Säljö (1976) highlighted links between students' engagement with their learning and their perceptions of summative assessment. This led to a substantial literature exploring and problematising these links. For example, Harlen and Deakin Crick (2003) and Gijbels and Dochy (2006) found that if students perceive a method of summative assessment as requiring understanding, they will tend to engage in deep learning but they noted that the link is not often straightforward. Indeed, a study concerning the introduction of portfolio assessment with students on a management course found that students' preferences for examinations decreased but also deep learning approaches decreased (Baeten, Dochy, & Struyven, 2008). That is, just introducing an innovative summative assessment method which the student prefers over a traditional one is not enough to increase deep learning approaches.

Birenbaum (2007) argues that understanding students' perceptions of, and preferences for, summative assessment is necessary for teachers to comprehend (and potentially influence) the factors which drive students' learning and lead to apparently different outcomes. Some evidence suggests that students generally prefer to be assessed by methods they perceive to be easy (e.g. multiple choice questions which they believe allow simple accrual of marks, Chan & Kennedy, 2002) and that they tend to believe that traditional summative assessment methods are detrimental to their learning (Sambell, McDowell, &

Brown, 1997). Much of this research has, however, neglected to consider the influence of context including the discipline of study and the type of higher education institution. Indeed, in recent years this omission has been strongly criticised because it can lead to unjustified generalisations of findings (Joughin, 2010).

In particular, little research has been undertaken with disciplines classified as hard/pure under the Biglan (1973) scheme, such as mathematics. One such study found that mathematics university students' preferences of summative assessment did indeed appear different to that predicted by the more generalist literature: Iannone and Simpson (2015) found that mathematics students tended to favour assessment methods which they perceived as fair and as good discriminators, rather than those which were easy. In a follow up study contrasting mathematics with education students, Iannone and Simpson (2016) found that while both groups looked for summative assessment methods which were good discriminators, the methods they thought of as being good discriminators were different. Mathematics students tended to prefer closed book examinations and education students tended to prefer projects. Of course, students in social sciences are likely to have very different ideas to mathematics students about how their subject is organised and studied. It has been noted that even at the elementary level students are much more goal oriented when learning mathematics than when learning social science — where they are more likely to believe that they could learn the subject by themselves (Stodolsky, Salk, & Glaessner, 1991). Therefore it seems important to understand what contributes to the formation of students' summative assessment preference in a specific discipline, as these are very likely to vary across disciplines. In what follows we summarise recent research that has addressed the questions of what factors influence summative assessment preference, both in psychology and in education.

A number of studies by Furnham and his team directly investigated some potential factors. Rather than discipline or epistemological beliefs, they explored the link between students' summative assessment preferences, IQ and personality traits (the so-called *Big Five*, see Goldberg, 1993). Furnham and Chamorro-Premuzic (2005) found that the Big Five personality traits were a bigger influence on summative assessment preferences than IQ or gender and the study uncovered various links between particular personality traits and summative assessment preferences. For example, they found that conscientiousness was correlated with preference for coursework and that neuroticism was negatively associated with closed book or oral exams. While Furnham, Christopher, Garwood, and Martin (2008) found significant correlations between deep learning and preference for traditional examinations and between surface learning and multiple choice questions, they noted that all the factors in their study accounted for, at best, 20% of the variance in summative assessment preference, arguing for the need to explore other factors.

In education, only one study has apparently explored the relationship between discipline-specific epistemological beliefs and summative assessment preferences (Watters & Watters, 2007). Undergraduate biochemistry students

in Australia were asked to complete a study process questionnaire and a small subset were interviewed about their epistemological beliefs. While the quantitative analysis from the larger group found predicted relationships between study approach and outcomes such as grade point average, the smaller qualitative study suggested links between epistemological beliefs and summative assessment preference. In this small sample, most students appeared to have naïve epistemologies — believing that learning is about memorising and regurgitating facts — and indicated their belief that examinations were the best way to assess understanding in their subject.

Taken together, existing research appears to predict a link between summative assessment preference and epistemological beliefs. However, it is important to explore further what we mean by (and how we measure) epistemological beliefs, particularly within a single discipline.

2.2 Students' beliefs about mathematics and their effect on learning

Given the lack of agreement in the relevant literature on the key components of epistemological beliefs (Limon, 2006) we start from a naïve general definition of such beliefs and will focus on existing literature on the effect of mathematics students' beliefs on their learning and engagement with the subject, highlighting factors related to epistemological beliefs directly.

Hofer (2001) defined epistemological beliefs as beliefs about knowledge and knowing, including

... the definition of knowledge, how knowledge is constructed, how knowledge is evaluated, where knowledge resides, and how knowing occurs.

Hofer (2001, p. 355)

The apparent simplicity of this definition is deceiving. Limon (2006) argues that although there is wide agreement on this definition, there is disagreement amongst researchers regarding the nature of the beliefs and when and how they develop. It is beyond the scope of this paper to review the literature about discipline-specific epistemological beliefs (for a comprehensive review see Muis, Bendixen, & Haerle, 2006). We focus instead on recent research on the effect that beliefs about mathematics and mathematics education (i.e. beliefs about how the learning of mathematics occurs) have on learning mathematics.

Schoenfeld (1989) appears to be among the first to establish a link between students' perceptions of and attitudes towards learning and their beliefs about mathematics, suggesting that students' mathematics beliefs affect their problem solving abilities. This work inspired investigations into the role of beliefs about mathematics in shaping engagement with problem solving activities (Schommer-Aikins, Duell, & Hutter, 2005) and on mathematical achievement and conceptual change (Mason, 2000).

A comprehensive review of research on beliefs about mathematics includes 33 empirical studies and categorises them in 5 broad categories (Muis, 2004):

- beliefs about mathematics: studies concerned with what students and teachers think is the nature and organisation of the subject,
- development of beliefs: studies concerned with how beliefs about mathematics change as students progress through school,
- effects of beliefs on behaviour: studies concerned with the effect of epistemological beliefs on student behaviour (for example on problem solving activities),
- domain differences: studies concerning the difference of epistemological beliefs held by students across disciplines,
- changing beliefs: studies concerning interventions that might influence change in student's epistemological beliefs, such as changes in instruction.

This review suggests that students generally hold beliefs about mathematics that hinder rather than help their learning and that such beliefs show clear effect on academic achievement. Muis also discusses some methodological problems she believes affect the studies: notably, reliability of the measures that have been used to investigate beliefs about mathematics and problems of self report methods. As well as reviewing research on teachers' mathematics epistemological beliefs, Depaepe, De Corte, and Verschaffel (2016) suggested there had been three main developments since Muis's review: the attention to epistemological beliefs about mathematics held by young children, the investigation of epistemological beliefs in a wider sense than that of Muis (to include for example perceptions of mathematics in the surroundings) and methodological changes with some studies, including at least some qualitative aspects. Again, however, Depaepe et al. suggested epistemological beliefs about mathematics are closely linked to learning, motivation and attainment. They also observed that the effect of epistemological beliefs is rarely studied in isolation, separate from the effect of other beliefs. Moreover, despite the appearance of some quantitative or mixed methods studies, relationships between epistemological beliefs and other factors are most often based on quantitative analysis of responses to survey instruments. It is important, therefore, to explore the nature of those instruments as measures of epistemological beliefs.

2.3 Measuring students' beliefs about mathematics and their effect on learning

Muis's concerns about the tools used to measure epistemological beliefs are echoed by much of the general literature and Limon (2006) argues it is grounded in the lack of agreement between different theoretical perspectives on epistemological beliefs.

Indeed, discipline-based epistemological beliefs have been conceptualised in two distinct ways, which affect how they have been measured. Some researchers have hypothesised that the factor structure of general epistemological beliefs (e.g. beliefs about knowledge and knowing in general) should be the same as that of discipline-specific ones (Schommer-Aikins, Duell, & Barker, 2003). Examples of this approach are the studies of Buehl, Alexander, and Murphy

(2002), investigating epistemological beliefs in mathematics and history, and Schommer-Aikins and Duell (2013) investigating epistemological beliefs for mathematics. Consequently, the tools used to measure subject specific epistemological beliefs in those studies are adaptations of tools constructed and validated for the measure of general epistemological beliefs.

So, many previous studies of mathematics students' epistemological beliefs had either adapted general epistemological beliefs questionnaires by adding the discipline they were interested in or by encouraging the participants to think about that discipline while completing the questionnaire. An example of the first type is in Buehl et al. (2002), comparing epistemological beliefs of mathematics and history students. One of their questionnaire items is "The process is much more important in math than the product" in the questionnaire for mathematics students and "The process is much more important in history than the product" for history students (Buehl et al., 2002, p. 424). An example of the second type is found in Hofer (2000). The questionnaire used in this study contains items phrased in generic terms and asks the student to think about the discipline considered when asking the questions. An example of a statement in this questionnaire is "All experts in this field would understand the field in the same way" (Hofer, 2000, p. 390).

In contrast to this discipline-general approach, others have argued that discipline-specific epistemological beliefs may have components which are distinctive to the disciplines and have thus developed scales that are constructed specifically for particular disciplines. In mathematics, an early attempt at designing and validating such an instrument came from Kloosterman and Stage (1992): the Indiana Mathematics Belief Scale with five dimensions:

- I can solve time-consuming problems
- There are word problems that cannot be solved using simple, step-by-step procedures
- Understanding concepts is important in mathematics
- Word problems are important in mathematics
- Effort can increase mathematical ability

This scale has been used in contexts outside the US where it originated; for example, Mason (2003) reports that the scale is valid and reliable when used with Italian students finding that only the factor "Word problems are important in mathematics" was not reliable in their sample. However, as Kloosterman and Stage (1992) note, their instrument is not designed to measure epistemological beliefs *directly*; instead it looks for the effect of such beliefs on problem solving. Thus it may not be suitable for studies outside that context.

Building on this idea of discipline-specific approaches, Op't Eynde and De Corte (2003) developed a scale independent of intended correlates. Their research was motivated by the wish to investigate the mathematics beliefs system of students as a whole and not to limit themselves to beliefs which affect problem solving behaviour, as much of the research had previously done. They designed and validated the MRBQ (the Mathematics-Related Beliefs

Questionnaire), following what they call a *bottom-up* approach, meaning that it

takes students' domain-specific belief systems as a starting point and analyses students' beliefs about knowledge and knowing within that domain. Op't Eynde, De Corte, and Verschaffel (2006, p. 62)

Op't Eynde and De Corte constructed the items in the questionnaire to reflect the results of existing mathematics education research in this area and were particularly influenced by the work of Schoenfeld (1989) on the relation between beliefs and problem solving, but they did not tie their design to this relationship. Behind the authors' choice there is the conviction that epistemological beliefs about mathematics do not (necessarily) follow the factor structure of instruments designed for general epistemological beliefs, as hypothesised by Hofer (2000) or Buehl et al. (2002). Having validated their questionnaire with secondary mathematics students Op't Eynde and De Corte (2003) arrived at the final version of the MRBQ which proposes a four-factor model for students' beliefs about mathematics:

- Beliefs about the role and functioning of their own teacher;
- Beliefs about the significance of and competence in mathematics;
- Mathematics as a social activity;
- Mathematics as a domain of excellence.

The MRBQ has demonstrated widely robust validity and usefulness. Andrews, Diego-Mantecón, Vankúš, Op't Eynde, and Conway (2011) found it was valid, reliable and had consistent factor structure for Slovakia, Spain and the UK. Andrews, Diego-Mantecón, Op't Eynde, and Sayers (2007) demonstrated that it was robust with respect to age, nationality and gender and Drobnič Vidic (2015) adapted it to investigate the link between university students' beliefs about mathematics and their engagement with context problems.

2.4 Research Questions

What appears from our review of the relevant literature is that epistemological beliefs are linked to many areas of the learning process and, particularly, to students' engagement with that process. It is also clear that there is a strong, if complex, link between engagement with learning and summative assessment preference. To date, however, the investigation of a direct potential link between epistemological beliefs about mathematics and summative assessment preferences has been neglected. Thus, we developed a study which investigated whether university mathematics students' epistemological beliefs do link to their perceptions of summative assessment. We were particularly interested in whether, first, there was *any* identifiable relationship as one might hypothesise from the literature and, if so, whether there are particular aspects of students' epistemological beliefs that feature strongly. That is,

RQ1 Is there a relationship between university mathematics students' epistemological beliefs about their discipline of study and their (summative) assessment preferences?

RQ2 If so, what sub-concepts play key roles in that relationship?

3 Methods

To investigate how students' perceptions of summative assessment are related to their epistemological beliefs about mathematics we constructed a two-part questionnaire, combining elements of existing, well-developed instruments. The study was approved by the Research Ethics Board of the first author's institution.

The first part of the questionnaire consisted of the Assessment Preference Inventory (API). Birenbaum (1994) developed the API to measure seven dimensions of assessment, but one (assessment type) has come to be used regularly and shows reasonably good reliability (Van de Watering, Gijbels, Dochy, & Van der Rijt, 2008). This was developed as a mathematics specific instrument by Iannone and Simpson (2015) by focussing on summative assessment methods which would be familiar to those studying for mathematics degrees, see Table 1. The questionnaire asks participants to rate the extent to which they would want their achievements in the course to be assessed by each of eight summative assessment methods, using a 5 point Likert scale (from *hardly at all* to *almost exclusively*). This part of the instrument followed the original (Iannone & Simpson, 2015) in that, to avoid ambiguity, each assessment method was followed by a short explanation¹.

The second part of the instrument was adapted from the MRBQ. As noted above, the MRBQ has a four factor structure, but one of those factors was relevant only to secondary school pupils. This was specifically targeted at identifying beliefs about the role of their mathematics teacher, which was considered sufficiently different from the role of a mathematics lecturer that is was not deemed relevant. While the word 'teacher' was used in items in the other factors (such as "I want to do well in mathematics to show the teacher and my fellow students how good I am at it.") it was felt that these items were still relevant to the university context. So, given the orthogonality of the factor structure and the robustness of the MRBQ to varying contexts and adaptations discussed above, we omitted the teacher factor questions and changed 'teacher' to 'lecturer' where relevant. Thus this section consisted of 27 statements which the students were asked to grade on a 5 point Likert scale (from *strongly disagree* to *strongly agree*). These covered items about students beliefs about the significance of and their own competence in mathematics (hereafter 'Significance'), mathematics as a social activity ('Social') and mathematics as

¹ To aid readability, in the rest of this paper we will shorten some assessment form (e.g. 'closed book exam' and 'open book exam' for the two forms of written examination)

Table 1 API assessment methods

Multiple choice examination	e.g. a test taken in an exam room, where for each question you have to select one response from five possible choices
Written examination with no support materials	e.g. a test taken in an exam room, with a separate booklet in which you write solutions, but where you are not allowed to use a calculator, books or any other support materials
Written examination with support materials	e.g. a test taken in an exam room, with a separate booklet in which you write solutions, where you are allowed to use a calculator, books or any other support materials
Weekly examples sheets	e.g. a test which you complete in your own time over the course of a week, based on the material covered in the course over that week
Project coursework	e.g. a piece of written work submitted in response to a question or problem, undertaken over the course of a number of weeks
Oral examination	e.g. working on a mathematical problem on a chalkboard or piece of paper with a tutor present who can provide suggestions or check errors as you work on it
Dissertation	e.g. a substantial piece of written work, on a set topic or problem, undertaken over the course of a long period, such as a term or two

a domain of excellence ('Excellence'). Example statements for each dimension are in Table 2 (for a complete list, see Op't Eynde & De Corte, 2003)

Table 2 Example of statements in the MRBQ per dimension

Significance	<ul style="list-style-type: none"> - I like doing mathematics - To me mathematics is an important subject - Mathematics enables people to better understand the world they live in
Excellence	<ul style="list-style-type: none"> - Those who are good in mathematics can solve any problem in a few minutes - Solving a mathematics problem is demanding and requires thinking, even from smart students - I am only satisfied when I get a good grade in mathematics
Social	<ul style="list-style-type: none"> - Making mistakes is part of learning mathematics - Mathematics is continuously evolving. New things are still discovered - There are several ways to find the correct solution of a mathematics problem

The instrument asked also for some biographical information such as gender and age but was completed anonymously. It was administered at two research intensive UK universities to year 1 and 2 students on degree courses in mathematics at the end of compulsory lectures. Students were informed of the aims of the projects and were told that they were not obliged to be involved, nor to return the survey. In total 98 students received the survey, 65 at one university and 33 at the other. 82 completed surveys were received (55 from

male and 26 from female student, with one declining to respond about their gender). The average age of the participants was 19.6 years. While students would have differential experience of these different assessment methods (disproportionately experiencing closed book exams and weekly exercise sheets), previous work with similar students has shown that students are able to interpret each appropriately and have at least some experience of each form (Iannone & Simpson, 2015).

3.1 Analysis

In order to investigate the structure of the responses to the summative assessment preferences inventory, we conducted a polychoric principal component analysis (pPCA) on the 8 assessment methods with orthogonal rotation (varimax). The sample size was acceptable (a subject-to-variable ratio of 10.25; Velicer & Fava, 1998). Kaiser-Meyer-Olkin test for sampling adequacy was acceptable (KMO=0.61) and Bartlett's test of sphericity suggested that the correlations between items were acceptable for pPCA ($\chi^2(28) = 98, p < 0.001$). Parallel analysis suggested extracting three components. Table 3 shows the component loadings after varimax rotation. The components make theoretical sense with the first component clustering together mainly items with presentational aspects (labelled 'Presentations'), the second clustering around assessments where there is access to support materials (labelled 'Access to materials') and the third focusses on greater or lesser complexity of response in traditional forms of testing (labelled 'Complexity').

Table 3 Loadings on components after rotation

Item	Presentations	Access to materials	Complexity
Oral Examination	0.86		
Project presentation	0.85		
Dissertation	0.71		
Weekly exercise sheets		0.78	
Project coursework		0.67	
Open book examination		0.65	
Multiple choice examination			-0.85
Closed book examination			0.78
SS Loadings	2.10	1.60	1.42
% variance explained	26	20	18
alpha	0.72	0.45	0.54

In addition, we scored each response to the MRBQ with the weightings provided by Op't Eynde and De Corte (2003) to obtain scores for Significance, Social and Excellence.

Recall that we were interested in whether there was a relationship between epistemological beliefs and assessment preference and, if so, how sub-concepts might be related. We examined the correlations between the components of

Table 4 Correlations between components of belief and assessment methods with p values

	Excellence	Social	Significance
Presentation	0.012 ($p = 0.91$)	-0.041 ($p = 0.71$)	0.02 ($p = 0.86$)
Access to materials	-0.081 ($p = 0.47$)	0.112 ($p = 0.31$)	-0.010 ($p = 0.93$)
Complexity of response	-0.003 ($p = 0.98$)	0.188 ($p = 0.09$)	0.455*** ($p < 0.0001$)

belief and the assessment methods. To correct for multiple tests we adjusted the alpha value using the Holm-Bonferroni sequential method. Table 4 shows those correlations and p values.

That is, the sole significant relationship is a positive one between students' beliefs about the significance of (and their competence in) mathematics and their preference for assessments which include complex responses. This is a relatively strong relationship – about 20% of the variance in preference of complex responses can be accounted for by the variance in beliefs about the significance of and students' own competence in mathematics.

We examined this in more detail, by looking at the individual correlations between responses to the questions of the MRBQ and the complexity of responses component of the assessment preferences. Amongst the strongest positive correlations for closed book examinations were:

- I prefer mathematics tasks for which I have to stretch myself in order to find the solution ($r = 0.40$)
- If I try hard enough, then I will understand the course material of the mathematics class ($r = 0.38$)
- Taking into account the level of difficulty of our mathematics course, the lecturer, and my knowledge and skills, I'm confident that I will get a good grade for mathematics ($r = 0.37$)

Amongst the strongest negative correlations for multiple choice examinations were:

- I believe I will receive this year an excellent grade in mathematics ($r = -0.40$)
- I can understand the course material in mathematics ($r = -0.37$)
- I like doing mathematics. ($r = -0.34$)

4 Discussion

The study suggests that the Significance factor (beliefs about the significance of and one's own competence in mathematics) appears to be the only factor in the epistemological beliefs model which links with summative assessment preferences, and even then, only with one component (related to the complexity of response). That is, in terms of our research questions, while there is evidence of a relationship between one aspect of a measure of epistemological beliefs

about mathematics and one aspect of assessment preference, this is neither pervasive nor persuasive.

Indeed, even for the relationship which does appear in our data — Significance with Complexity — it is possible to question whether this genuinely reflects a link between epistemological belief and assessment preference. In the development of the MRBQ by Op't Eynde and De Corte (2003) the Significance factor appears to combine two ideas: beliefs about students' own ability in mathematics and beliefs about relevance of mathematics. The first of these might more accurately be described as self-efficacy, with only the second fitting well with the notion of epistemological belief. Indeed Op't Eynde and De Corte interpreted the conflation of two ideas in one factor as suggesting that confidence in one's own abilities as a mathematician varies consistently with beliefs in mathematics as important. On reflection, this seems surprising as it brings together a belief about one's self and a belief about the nature of the subject matter. This touches again on the question of what beliefs count as epistemological: are beliefs about one's self *epistemological* beliefs in the sense defined earlier?

That is, it may be that the one clear relationship found in our data — between the 'Significance' component and the preference for complex responses — may not in fact reflect a link between epistemological belief and summative assessment preference at all. Instead it may reflect a relationship between self-efficacy and summative assessment preference, which may make sense in terms of existing literature.

Recall that Iannone and Simpson (2015) found that mathematics students prefer to be assessed by summative assessment methods that are good at discriminating academic ability, and that they believed that the summative assessment which is best at discriminating for academic ability in mathematics is the closed book exam. In the current study, we found positive correlations between statements about confidence in mathematical ability with preferences for summative assessment by closed book exams. We also found a negative correlation between preference for summative assessment by multiple choice with mathematics having great value and being interesting in learning mathematics. Reading these results together seems to indicate that self-efficacy plays an important role in students' preferences of summative assessment methods.

If closed book exams are perceived to be good discriminators of ability then it is reasonable to think that students who believe they are good at mathematics will prefer to be assessed by summative assessment methods which discriminate on ability. On the other hand, students who think they are weak mathematicians (i.e. have low self-efficacy) will want to be assessed by methods which do not discriminate on ability in the subject. In this way the results of this current study corroborate and further explain the results in Iannone and Simpson (2015).

However, perhaps the more interesting outcome of the study is that we *did not* find a clear, pervasive link between students' perceptions of what mathematics is — discipline-based epistemological beliefs represented in the MRBQ by the factors Excellence and Social — and their summative assessment pref-

ferences as appears to have been predicted by previous research. There may be a variety of reasons for this.

The apparent lack of relationships may be an artefact of the nature of the sample: the study looked at a relatively homogenous sample of previously high achieving students at two research intensive universities in the same country. Of course, it would be interesting to investigate what happens with a larger and more varied sample (across years of study, different institutions, countries and varied previous achievement) and whether with a larger sample we can see links with the other factors which we cannot detect in this study.

However, the lack of relationship may also be related to concerns about the way epistemological beliefs are measured: existing research has raised doubts about the measures used in empirical studies. Some (e.g. Schommer-Aikins, 2004) believe that it is possible to separate the study of epistemological beliefs from context and content, hence rendering a category like the Social category in the MRBQ superfluous and potentially confusing the measure. Others (e.g. Greene & Seung, 2014; Muis, Duffy, Trevors, Ranellucci, & Foy, 2014) are critical of these forms of survey instrument, stressing that in a complex field such as that of epistemological beliefs researchers cannot be sure that there is a shared meaning for key terms used in questionnaires. In this case, the questionnaire may be measuring something — after all, the MBRQ has been found to be consistent and widely applicable — but not necessarily what the designers intended. This suggests the need for qualitative validations of existing epistemological beliefs questionnaires (Greene & Seung, 2014; Muis et al., 2014) and for larger mixed methods studies (Muis, 2004).

Lastly we cannot, of course, exclude the possibility that there is no link between epistemological beliefs about mathematics and summative assessment preferences and that the only link is between self-efficacy and perceived difficulty of the summative assessment, even if the literature reviewed above all points directly or indirectly to such a link.

5 Concluding Remarks

This study appears to be the first designed to investigate a deceptively straightforward question, which seemed to emerge naturally from previous studies: whether (and how) epistemological beliefs may be related to summative assessment preferences.

Understanding what shapes summative assessment preferences in mathematics is important for many aspects of teaching and learning, and for classroom practice. Although we have seen how simply changing summative assessment method does not necessarily change approaches to learning (Baeten et al., 2008), understanding better the nature of assessment preferences and the factors that influence them would help instructors to design summative assessment which not only fosters deep learning but also helps students' mathematics epistemological beliefs to become progressively more sophisticated. The findings from the current study show, again, how complex the field of

epistemological beliefs really is. Despite the doubts raised regarding the methods of investigation, it is possible that we do not yet fully understand what are discipline-specific epistemological beliefs, what relationships they have to learning and how to measure them. Yet this construct seem to affect many aspects of the student learning experience.

In the conclusion of her review of the literature Muis (2004) writes:

It may be the case that personal epistemology is similar to self-efficacy, a person's confidence that he or she can successfully complete a specific task (Bandura, 1997), such that personal epistemology is more task or content specific. As such, measuring students' beliefs should also be more specific to the task or content area. If there are significant differences within a domain, then measures used to assess students' beliefs should be sensitive to these differences. Results of such studies may help to explain methodological issues in research on personal epistemology.

Our study was not designed to find a link between self-efficacy and summative assessment preferences, although our results suggest the existence of this link. That we did indeed only find a significant relationship between self-efficacy and one component of summative assessment preference appears to support Muis's statement. This may further bolster the need for more research to ascertain whether the reason for this resides in the methodology that is often used or in the very notion of 'epistemological beliefs'.

Conflict of interest statement: The authors know of no conflicts of interest.

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